GEOPHYSICAL INSTITUTE

of the

UNIVERSITY OF ALASKA

INVESTIGATION OF AURORAL ZONE IONOSPHERIC FORWARD SCATTER

FINAL REPORT

Covering the Period

1 April 1965 - 31 December 1966

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

under

Contract NSR 02-001-020

Principal Investigator

Glenn M. Stanley

Report Approved By:

Keith B. Mather
Director

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

The purpose of the work performed under this contract was to conduct studies of the ionosphere in the vicinity of the midpoint of an auroral zone ionospheric forward scatter circuit. The particular circuit chosen to be investigated had its end points at Point Barrow, Alaska and Anchorage, Alaska. The midpoint of the circuit was near the village of Allakaket, Alaska slightly south of the zone of maximum auroral occurrence. The specific intent of the program was to obtain and analyze data, which would provide information leading to an understanding of large enhancements which appear on signals propagated by ionospheric forward scatter. These enhancements (often as much as 60 db) last from a few seconds to as much as several hours, and have been attributed to layers or patches of sporadic E appearing near the midpoint of the scatter circuit. Detailed investigations concerning the causes of the enhancements in the signal levels have not been previously made in the auroral zone.

Recently, a series of forward scatter experiments designed to investigate polar cap absorption events has been supported by Manned Spacecraft Center, NASA under the direction of D. K. Bailey, ITSA/ESSA and M. A. Pomerantz, Bartol Research Foundation. The experiments include the design construction, and operation of a series of ionospheric forward scatter circuits in the northern hemisphere. In addition, there were four circuits operative in Antarctica in conjunction with the IQSY program. Three circuits are presently in operation in or near the northern auroral zone. The frequencies of the circuits are all in the vicinity of 23 MHz and it is planned to increase the frequency of the circuits as necessary for later studies as the sun becomes more active. The main purpose of the forward scatter network is to provide a (real time) proton event warning system for use in conjunction with Project Apollo. The enhancements attributed to sporadic E could cause serious operational difficulties with such a system and the data obtained at Allakaket, when analyzed, should contribute markedly to the proper design of the warning system.

The ionospheric forward scatter circuit between Point Barrow and Anchorage was chosen as being the most practical circuit for investigation. The transmitted power (Point Barrow) is 500 watts cw fed to a five element Yagi antenna. The propagated signal is received at Anchorage on an identical antenna connected to a very narrow band receiver. The transmitting and receiving antenna are installed so that their main lobes intersect at approximately 80 km in the vicinity of Allakaket, Alaska, a remote native village in Central Alaska just south of the auroral zone.

During the performance of the contract, a site was established at Allakaket, Alaska. An ionosonde, two all-sky cameras, a 30 MHz riometer, and magnetometer were operated nearly continuously during the winter period 1965-1966. Data from these equipments was processed and scaled.

II. SCOPE

General

The Geophysical Institute of the University of Alaska has been engaged in the operation and maintenance of the receiving equipment of one of the 23 MHz forward scatter circuits (Annette Island to College, Alaska). Arrangements were made with MSC and ITSA to utilize data from that circuit and to obtain the data from the Point Barrow to Anchorage circuit. Copies of all data are to be retained at the Geophysical Institute. The Geophysical Institute also operates a C3/C4 ionosonde at College under contract with ITSA/ESSA. Further, the Geophysical Institute is engaged in other researches including the operation of all-sky cameras, riometers, and magnetometers. The data from these other equipments will be used to supplement the data obtained under this contract.

Operational Plan

The following steps were planned to be carried out during the period of the contract:

a. Establish a field site at Allakaket, Alaska.

b. Install a diesel generating plant at Allakaket to provide lights and power for the operation. It was anticipated that approximately 15 kw of power would be necessary for the operation.

c. Provide suitable quarters at the village for site personnel.

d. Install scientific equipment to include C3/C4 ionosonde, a 30 MHz riometer, two all-sky cameras, and a magnetometer.

e. Install a communications system between Allakaket and College. It was proposed to install a VHF link between Allakaket and the White Alice communication station at Indian Mountain, located approximately 60 miles to the south.

f. Operate the field site for approximately 60 selected days during the winter period 1965-1966.

g. Analyze the data obtained at the site and procure and analyze supplementary data from other experiments.

h. Provide a final report covering the work done.

The tentative time schedule for the various phases of the project were as follows:

a. 1 April 1965 - 30 June 1965. Make preliminary arrangements, obtain and assemble equipment.

b. 1 July 1965 - 1 September 1965. Transport equipment and supplies to Allakaket. Construct housing, construct equipment shelters, erect antennas, install equipment, install communications system and occupy the site.

c. 1 September 1965 - 1 February 1966. Operate site for approximately 60 days.

d. 1 February 1966 - 15 August 1966. Analyze data. Return equipment to Geophysical Institute.

e. 15 August 1966 - 31 December 1966. Prepare final report.

f. 30 September 1966. End of project.

III. WORK DONE

Estimates of the weight and dimensions of the equipment and supplies to be shipped to Allakaket were made. The total weight of the equipment and supplies not including diesel fuel appeared to be near 40,000 lbs. The instrument van (26' x 7' x 7') weighed approximately 8000 lbs and the diesel generator weighed about 5000 lbs. As Allakaket is not served by road or rail and was possessed of a small (approximately 1000 ft) landing strip it was necessary to determine whether it was feasible to ship the equipment and supplies by river from Fairbanks. Because only one barge a year goes to Allakaket (in June) it was found that it would not be possible to have the equipment and supplies ready on time to be shipped on the barge. The Alaska Air National Guard was asked if it would be possible for them to fly all of the equipment into Allakaket if the runway were repaired and lengthened. It was determined that the operation would be marginal but possible and preliminary arrangements were made with them to transport the equipment and supplies subject to improvements on the runway. Subsequent developments (severe flooding of the Koyukuk River causing further damage to the Allakaket air strip) caused a change of plans. It was decided to airlift all of the equipment and supplies to Bettles Field, Alaska (approximately 75 miles upstream from Allakaket) using the Air National Guard C123 type aircraft. There were no charges for this airlift. It was then necessary to ship the equipment and supplies to Allakaket via river. No commercial means of river transportation is available between Bettles and Allakaket. Six army assault boats were procured from surplus at Elmendorf Air Force Base (near Anchorage, Alaska) for use in the final stage of the shipment.

Arrangements were made with the Department of Education, State of Alaska for a joint effort in power production at Allakaket. The Department of Education had a small diesel generator, which was operated by the local school teacher, and had a large supply of diesel fuel. It was jointly decided that it would be mutually beneficial if only one power plant was operated. The agreement was made that the Geophysical Institute would operate a power plant of sufficient capacity for the school and the scientific project and the Department of Education would furnish the fuel for the operation. As commercial shipping rates from Nenana, Alaska (nearest supply port) to Allakaket are $3.64/100 lb this represented a major saving to the project.

As there were no commercial communications at Allakaket, it was felt necessary to establish a communications link between there and Fairbanks. Arrangements were made with the Defense Communications Agency to supply facilities between Indian Mountain, Alaska (approximately 40 miles from Allakaket) and College. In addition a VHF communications link was operated between the site and Indian Mountain.

ITSA/ESSA provided a C3/C4 ionosonde for the project. The sounder was modified and tested at Boulder, Colorado by ITSA and was shipped to College.

The diesel generator for the site was inspected and repaired by a commercial firm at Fairbanks. A shelter for the generator was obtained and the generator and power distribution system was installed in the shelter.

License application for operation of the ionosonde was processed and sent to the FCC. Permission to erect the towers at Allakaket was obtained from the FAA.

A modern 35 mm all-sky camera was obtained on loan from Stanford Research Institute and a standard all-sky camera shelter was constructed for the camera. In addition, arrangements were made to move the IQSY 16 mm all-sky camera and shelter from Bettles, Alaska to the site at Allakaket.

A 30 MHz riometer was obtained for use at the site. It was necessary to construct a suitable antenna system for the riometer and prepare the equipment for shipment.

An Askania magnetometer was obtained and a non-magnetic shelter was constructed for use with it.

The ionosonde antenna mast, antenna and associated hardware were obtained and all parts were precut and prepared for erection.

The basic instrument shelter, a 26' van, was obtained and prepared for use at the site.

Arrangements were made for the use of the only unoccupied building at Allakaket for housing for the site personnel. The building was in severe disrepair and use of it was obtained in return for repairing it.

During the last few days of June, the Alaska Air National Guard airlifted most of the supplies and equipment for use at Allakaket to Bettles Field, Alaska. The equipment was moved to an area adjacent to the Koyukuk River with the aid of the FAA station personnel and their equipment. The arrangements for assistance by the FAA were made through the FAA Area Manager at the Fairbanks Office and full and willing co-operation from all FAA personnel was obtained.

It was found that the Koyukuk River was in flood stage and was likely to remain that way for some time as a considerable amount of snow was still left in the mountains. Rather than to delay the installation until low water it was decided to attempt to move the equipment with the river in flood. Six surplus army assault boats were assembled in such a way as to make three boats (each 20 ft long) and were modified to permit mounting an outboard engine on each. The equipment and supplies were loaded onto the boats and transported to Allakaket, a distance of 75 miles by river. Figures 1 through 4 show some of the freighting operations. Despite engine failures, high water, serious rapids, and very severe mosquito conditions all of the equipment and supplies were moved to Allakaket within about two weeks.

The instrument trailer was set in place, land was cleared for the erection of the ionosonde antenna, the generator was installed and the power distribution system was completed, the ionosonde antenna (115 ft in height) was erected, living quarters were repaired, all-sky camera buildings were installed, and the various instruments were set up and tested.

During the summer, mosquito conditions were very severe. It was necessary to procure mosquito spray and to have the area sprayed twice from the air in order for workmen to remain outside. Until the area was sprayed, it was necessary to wear headnets and gloves most of the day.

The Allakaket airstrip was further damaged by the flooding conditions and became unsafe for operation. It was necessary to spend a considerable amount of time in repairing the airstrip. A D-7 bulldozer and a pull grader were procured from the village and the strip was lengthened, widened and smoothed.

A station operator was employed and trained at College. After a short training period the operator was sent to Allakaket.

Although original plans called for operation of the Allakaket field site for 60 selected days during the winter period 1965-1966, it was decided to attempt to operate continuously during the winter period. Three factors contributed to this decision:

a. Original installation costs were somewhat less than anticipated;

b. The cost of opening or closing the station for short periods would have been very high; and

c. The obvious advantage of securing continuous data.

Operation of the station began on a limited basis in early September with completion of installation of the ionosonde and the riometer. The all-sky cameras and magnetometers did not commence operation until about 1 November.

Operation of the site continued more or less routinely until 3 March 1966 when it became obvious that fuel supplies had dwindled to the point that further operation would not be possible without shipping additional fuel to Allakaket. Further, although installation costs had been low, operational costs had been high and funds were limited. The site instrumentation was turned off on 3 March 1966 and preparations were made for storage of instruments and equipment at Allakaket until June 1966, when the river barge made its yearly trip. In June, all equipment was returned to Fairbanks by barge and rail.

IV. RESULTS

Data Obtained

During the period of the contract, ionosonde data were taken on a routine basis during the period 11 September 1965 to 3 March 1966. A 30 MHz riometer was operated during substantially the same period. An Askania magnetometer and two all-sky cameras were operated at the site during the period 3 November 1965 to 3 March 1966. The quality of the data are surprisingly good considering the adverse conditions under which it was obtained. Some short periods of instrument failure and operator error did occur but in the main the data are complete.

Data Scaled

As of this time all of the ionograms have been reduced to tabular values at occurrence, type, vertical height, top or critical frequency, and other parameters for all sporadic E seen on the ionosonde.

All 30 MHz riometer records have been reduced to 15 minute values of cosmic noise absorption.

All-sky camera records have been reduced to tabular values of types of aurora, brightness, and position of aurora with respect to the midpoint of the forward scatter path.

Magnetometer records have been scaled.

Scaling of the above records has been done both during the period of the contract and subsequently by personnel at ITSA/ESSA supervised by Dr. D. K. Bailey of that organization.

Analysis

The analysis of the data obtained at Allakaket is not yet complete. Work continues on the data by G. M. Stanley (presently at Radio Physics Laboratory, Stanford Research Institute) and D. K. Bailey (ITSA/ESSA).

Several oral and written papers have been presented using the data obtained at Allakaket and more are in process or planned. It is anticipated that the analysis of the data will have been completed by Fall 1968.

Appendix I contains a copy of a paper published in JGR in which some of the Allakaket data were used.

Following is a partial list of papers in which the Allakaket data were used:

Stanley, G. M., Studies of the sub auroral zone nighttime F-region, Commission III, URSI, Washington, D.C., April 1966. URSI, Washington, D.C., April 1966.

Bailey, D. K., Some quantitative aspects of the precipitation of relativistic and less energetic electrons in and near the auroral zone, Conjugate Point Symposium, Boulder Colorado, June 1967 (Summary enclosed in Appendix I).

In addition, D. K. Bailey presented a paper to IQSY/COSPAR Joint Scientific Symposium, London, July 1967 (in press).

Further, Bailey and Stanley are collaborating on papers which will be submitted for publications within the next few months.

Figure 1 Unloading instrument van from Alaska Air National Guard C123 at Bettles Field, Alaska

Figure 2 All-sky camera shelter and ionosonde antenna on Koyukuk River.

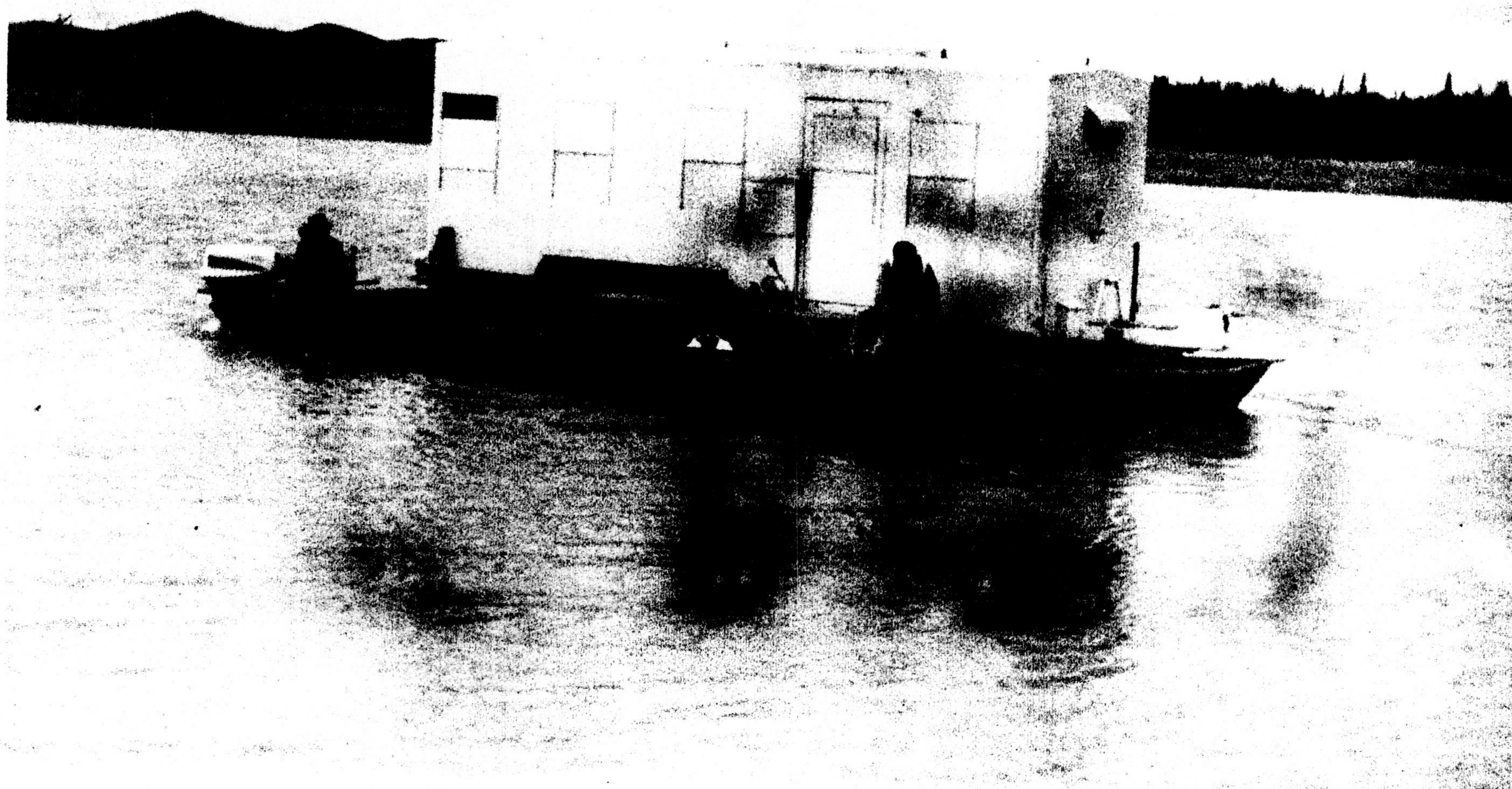

Figure 3 Instrument van on river boats at Bettles.

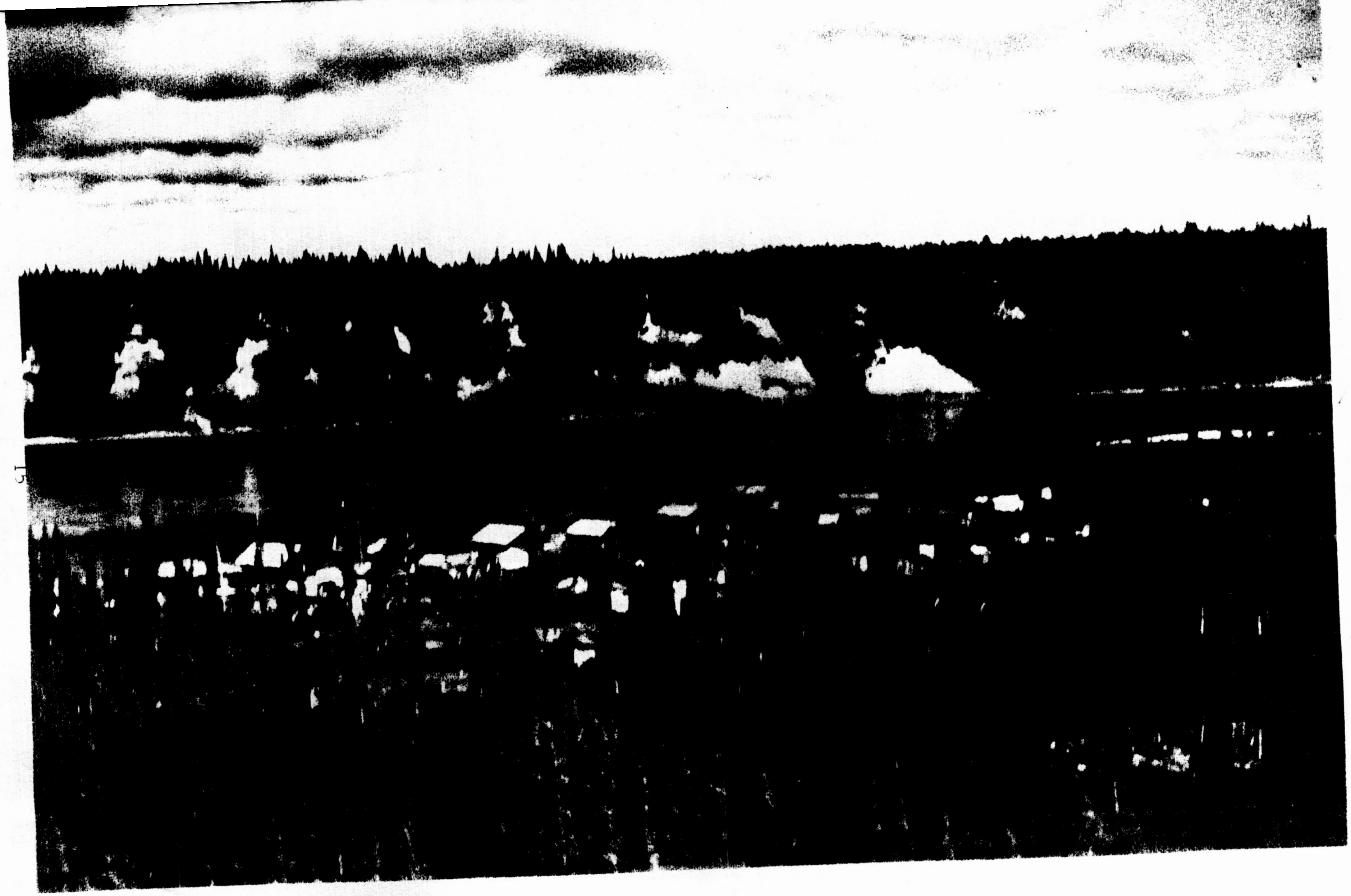

Figure 4 View of the village of Allakaket taken from the tower of the field site.

APPENDIX I

SOME QUANTITATIVE ASPECTS OF THE PRECIPITATION OF RELATIVISTIC AND LESS ENERGETIC ELECTRONS IN AND NEAR THE AURORAL ZONE

D. K. Bailey

Environmental Science Services Administration, Boulder, Colorado

Summary

Unmistakable daytime decreases in the intensity of radio signals propagated at a sufficiently low frequency (about 23 Mc/s in the present program) by ionospheric forward scattering result from special causes that produce intense and abnormal ionization below the scattering region. Three causes of such ionization have been identified:

- solar X-rays emitted during flares and affecting only the illuminated hemisphere,
- solar protons, together with a small fraction of heavier particles, emitted during some flares, and observable, for example, as the PCA phenomenon in the polar caps, and
- electrons precipitated from the vicinity of the boundary of the trapping region, and observable in the regions bounded approximately by L-values of 4 and 8.

The first of these causes will not be discussed further.

For present purposes it is assumed that the particles arrive approximately isotropically over the upper hemisphere. For a scattering height of 70 km, typical of daylight conditions, there is an effective atmospheric cutoff or threshold energy:

- for protons of about 10 MeV, and
- for electrons of about 400 keV.

The latter energy value provides the justification for the term REP event or relativistic electron precipitation event that has been assigned to the cases of absorption ascribed to the third cause identified above.

At night when the scattering region lies at about 85 km, a height below which the electron removal processes grow progressively more effective than during daylight, riometers may observe considerable absorption, but decreases in the scatter signal are not observed either for proton or electron precipitation. During electron precipitation, however, Es-propagation is often observed; it can be accounted for satisfactorily as resulting from layer formation in the 95 to 110-km region by much softer precipitating electrons than produce the daytime absorption. Under some conditions especially after auroral break-up the Es-propagation, observed obliquely over the scatter paths near the auroral zone, exhibits unmistakable evidence of absorption. The contribution of auroral hydrogen to the r-type of Es that is found to be virtually exclusively responsible in winter (when the detailed observations were made) for the oblique propagation identified as Es-propagation over the scatter path is not considered important for Es having the required critical frequencies of about 5 Mc/s and greater.

With some unavoidable temporal and spatial smoothing, exponential energy spectra for the precipitating electrons are proposed. These spectra are found to reconcile, often quantitatively, the forward scatter observations with simultaneous riometer, ionosonde, all-sky camera, and magnetic observations made from a point under the midpoint ($L = 5.7$) of the more northern of the two scatter paths near the auroral zone. The exponential spectra can also be reconciled with simultaneous observations of scatter signals and balloon observations of auroral bremsstrahlung X-rays, made both by day and by night, in the vicinity of the midpoint ($L = 4.6$) of the other scatter path.

Particular acknowledgements are due as follows:

- to C. C. Taieb who, while a guest worker at the Bartol Research Foundation of the Franklin Institute, made the as yet unpublished calculations of the required electron-ion pair production profiles for precipitating electrons,
- to G. M. Stanley who, while at the Geophysical Institute of the University of Alaska, was responsible for organizing the program of observations under the midpoint of the scatter path from Barrow to Anchorage, and for the reduction of much of the data obtained,
- to J. R. Barcus, of the University of Denver, who supplied not only the balloon data from the vicinity of the midpoint of the Annette to College path, but also much useful discussion,
- to K. W. Sullivan, who has been in charge of the forward scatter data from the start of the program in February 1964 to the present time, and who has been ever alert to important nuances in the data.